

1994

A Study Comparing the Design and Engineering Problem-solving Abilities of Students that have Received Varying Amounts of Prior Mathematical Instruction

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**A STUDY COMPARING THE DESIGN AND ENGINEERING
PROBLEM-SOLVING ABILITIES OF STUDENTS THAT
HAVE RECEIVED VARYING AMOUNTS OF PRIOR
MATHEMATICAL INSTRUCTION**

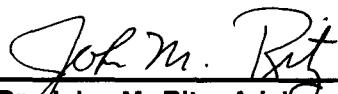
**A research study presented to
the graduate faculty of the
Department of Occupational
and Technical Studies
Old Dominion University**

**In partial fulfillment of the
requirements for the degree
Master of Science in Education**

**By
Eric M. Fischer, M.S.
August, 1994**

This study was prepared by Eric Fischer under the direction of Dr. John M. Ritz in OTED 636, Problems in Education. It was submitted to the Graduate Program Director as partial fulfillment of the requirements for the Master of Science in Education Degree.

Approved By:



**Dr. John M. Ritz, Advisor and
Graduate Program Director**

Date 6-22-94

TABLE OF CONTENTS

	Page
Signature Page	i
Table of Tables	iv
Table of Figures	v
Chapters	
I. INTRODUCTION	1
Statement of Problem	2
Hypothesis	2
Background and Significance	3
Limitations	5
Assumptions	6
Procedures	7
Definition of Terms	9
Overview of Chapters	11
II. REVIEW OF LITERATURE	13
Modern Educational Systems- A Global Perspective	13
Integrating Mathematics and Technology Instruction	21
A Mathematics Instructional Paradigm	25
Programs In Action	29
Summary	32

III. METHODS AND PROCEDURES	35
Introduction	35
Population	35
Research Variables	37
Instrument Design	39
Laboratory Procedure	40
Methods of Data Collection	42
Statistical Analysis	43
Summary	44
IV. FINDINGS	45
Reporting of Data	46
Statistical <i>t</i> -Test Calculations	53
Summary	56
V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS	57
Summary	58
Conclusions	60
Recommendations	63
Bibliography	66

TABLE OF TABLES

	Page
Table 1 Groups of Students With One Year of Mathematics Courses	46
Table 2 Groups of Students With Two Years of Mathematics Courses	47
Table 3 Groups of Students With Three Years of Mathematics Courses	48
Table 4 Groups of Students- Each Having One, Two, or Three Years of Mathematics Courses	49
Table 5 Mean Efficiencies of Groups With One Year of Mathematics Courses	49
Table 6 Mean Efficiencies of Groups With Two Years of Mathematics Courses	50
Table 7 Mean Efficiencies of Groups With Three Years of Mathematics Courses	50
Table 8 Mean Efficiencies of Groups With One, Two, and Three Years of Mathematics Courses	51

TABLE OF FIGURES

	Page
Figure 1 Bridge Testing Apparatus	41
Figure 2 Comparisons of Major Group Efficiency Levels	52

CHAPTER I

INTRODUCTION

This study objectively examined and compared the problem solving abilities of sixty high school students in grades nine through twelve. The students worked within a cooperative learning environment in teams of three. Each team was selected according to the number of high school math courses that each member had successfully completed. Each team engaged in a technology oriented instructional activity and constructed load bearing scale models of truss bridges from student-generated original plans, basswood, and glue. Once construction was completed, the bridge models were load tested with increased loads until structural failure resulted. Quality of structural design was determined to be directly associated with higher loads withstood by structures. A relationship between quantity of mathematics instruction received by students and higher loads resisted by their bridge models was

to be determined.

The study was undertaken to determine if the completion of high school mathematics courses will have a positive influence upon a student's problem-solving skill development. This would assist in determining if mathematics prerequisites were essential for the study of technology education within America's high school classrooms.

Statement of Problem

The problem of this study was to compare the problem solving abilities of students in grades nine through twelve that have completed either one, two, or three, thirty-six week courses in the subject area of mathematics in order to determine how much mathematical instruction is necessary as a prerequisite to the successful completion of instructional activities integral to the contemporary high school technology education curricula.

Hypothesis

H₁: High school students that have successfully completed two or three thirty-six week high school courses in mathematics are more capable of solving problems encountered during

instructional activities in high school technology classes than are high school students that have completed only one thirty-six week high school course in the area of mathematics.

Background and Significance

A strong back, the willingness to work, and a high school diploma were once all that was needed to lead a life in America. They are no longer. A well developed mind, a passion to learn, and the ability to put knowledge to work are new keys to the future of our young people, the success of our businesses, and the economic well-being of the nation. Today's high school students must be able to think creatively, use appropriate mathematical techniques, and implement sound plans of action when providing solutions to practical problems (S.C.A.N.S., 1991, p. 1).

Teachers are entrusted with the responsibility of structuring effective learning environments, meeting student's needs, reaching school's overall educational goals, implementing new curricular standards, and developing themselves professionally. Educators are not only shaping skills, but also the accompanying attitudes of our nation's future leaders of business, government, academia, the media, medicine, social sciences, natural and physical sciences, and technology. Those empowered with

mathematical know-how and confidence today will be the leaders of tomorrow (Lynch and Olmstead, 1993, p. T6). It is also recognized that many of today's students are not prepared for tomorrow's jobs (National Research Council, 1989, p. 1).

The real challenge for American education is to provide improved foundational education in basic skills: reading, writing, language, mathematics, communication, problem solving, and reasoning. This is especially urgent for disadvantaged youth who have serious learning disabilities. School systems must reevaluate the role of vocational education in American education and reassess current high school curriculum to meet the challenges of global competition (Ryan, 1992, p. 36).

A school subject gaining importance is technology education. Technology is the study of the application of knowledge, creativity, tools, and skills to solve practical problems and thereby extend human capabilities (Todd, McCrory, Todd, 1985, p. 3). Technology education, a curriculum developed within the vocational education track, provides learning experiences as means for integrating the total school curriculum. It is particularly adept at reinforcing and enriching concepts integral to various mathematics curricula. High school students must be somewhat familiar with the laws developed for the manipulation of the terms

used in mathematics. The designer also finds the manipulation of mathematical terms to be useful; however, mathematics is most useful to the designer as a tool for efficiently communicating precise information. At each step of the design process, ideas that can be expressed mathematically will be communicated quickly and with little chance of being misunderstood (Rose, 1992. p. V1-V2). In order for America's students to participate productively within a growing information and production based economy, they must be able to utilize a sound foundation of mathematical and technological skills when creatively solving problems.

Limitations

The following limitations should be considered when reviewing this research study:

1. The students participating in this study are from varied socioeconomic backgrounds.
2. The two teachers providing instruction to the student groups are using the same instructional materials and supplies. There may, however, exist slight differences in each teacher's instructional delivery.
3. Churchland High School is in an urban neighborhood. Therefore, the results of this study may not be consistent with

results in similar studies done at schools in rural or suburban neighborhoods.

4. Students in grades nine through twelve that participated in the study were randomly selected from the student population of Churchland High School mathematics and technology classes.

5. Bridge building instructional materials were published by Pitsco, Incorporated.

Assumptions

When considering the parameters of this study, it should be assumed that the following conditions do exist and are true:

1. All instruction related to this problem will be taught using the same instructional materials and supplies.

2. Individual basswood strips share the same mechanical properties.

3. All materials will be distributed to groups in equal amounts and at random.

4. Destructive testing will be conducted in a standard fashion and tests will be in random order.

5. The thirty-six week courses in math are taken by students in the same sequence.

6. Time constraints on instructional activities are the same

for all groups.

7. The model bridge building instructional activity used in this study is appropriate for use during first year high school technology education classes.

Procedures

The research was conducted in order to compare the design and engineering problem solving abilities of Churchland High School students who have already completed either one, two, or three thirty-six week courses in mathematics. Five homogeneous teams were made up of students who have completed one high school course in mathematics. Five homogeneous teams were made up of students who have completed two high school courses in mathematics. Five homogeneous teams were made up of students who have completed three high school courses in mathematics. Five heterogeneous groups were each made up of three students, the first having completed one high school course in mathematics, the second having completed two high school courses in mathematics, and the third having completed three high school courses in mathematics. The heterogeneous groups provided for an experimental control group.

All of the students that participated in this study received

instruction concerned with the subject of bridge construction and the application of mathematical concepts within project applications. Each group also received model building supplies. All models were subject to the same problem goals and constraints.

All groups were given approximately fifteen hours at about one hour per day to review key concepts and complete their models. Upon completion of all models, destructive testing was undertaken. The quantity of weight at failure for each model was then entered into records so that further statistical analysis could be done.

Relationships between the amounts of mathematical background and the strength of bridge models will be analyzed. It will be investigated in order to determine if math provides better solutions to design and engineering problems, and if there is a need for mathematical prerequisites for students enrolled in high school technology education courses.

Definition of Terms

The following information is provided to insure that the reader of this study has an understanding of terms used that may be abstract or unfamiliar.

Abutment- The supporting structure at either end of a bridge.

Basswood- A species of tree from which we get light, soft, and durable wood.

Bridge- A structure built over a river, railroad, highway, buildings, or other obstacles to provide a way across for vehicles and pedestrians.

Deck- The surface of a bridge which vehicles and pedestrians cross upon.

Eye-Bolt- A threaded bolt with a loop bent into the non-threaded portion of the body.

Failure- The point at which elements within the model fracture and parts begin to separate from each other.

Fixed Bridge- A bridge which remains stationary and relies upon no moving mechanical systems in order to span a gap.

Gap- The area between two masses being connected by a bridge.

Load- The weight which must be supported by the bridge structure, generally divided into:

A- Live Load- The variable weight of forces acting upon a bridge structure including rain, wind, snow, traffic, and gravity.

B- Dead Load- The weight of the structural members that the bridge is made of.

Model- A small representational copy of a structure.

Polyvinyl Resin Glue- A water-based plastic adhesive used to bond wooden parts together.

Span- The measured length of space between two points.

Structural Failure- The point at which elements within the model fracture and parts begin to separate from each other.

Substructure- Both the supporting elements of a bridge below the deck and the bridge's abutments.

Superstructure- The elements of a bridge which lie above the deck.

Through Bridge- A bridge which has a superstructure which passes over and to the sides of the deck. Vehicles and pedestrians crossing a through bridge will pass through the actual superstructure.

Truss- A rigid framework of beams, girders, and bars connected in triangular sections and used to support a bridge.

Overview of Chapters

Contemporary American educational systems have become disengaged with the overall needs of industries now active within today's global marketplace. The need for curricular changes

within our schools is evident. Many school systems throughout the nation are in the process of making necessary changes within their curricular content and delivery systems, however, the need for a logical integration of course sequencing has not been evaluated thoroughly. Many students being thrust into state-of-the-art technology programs throughout the nation lack a sound foundational skill level in the area of mathematics. Technological studies and skill development within the technology classroom is therefore often hindered.

The following chapters will review the literature written by experts in the field of education and present their findings concerning student's needs for a broad and in-depth foundation of mathematical skills in order to successfully participate within contemporary technology education instructional activities. The methods and procedures used in the study will be discussed in Chapter III. The findings of the research study will be presented and explained in the text of Chapter IV. Chapter V of the study will include a summary of what was learned as a result of the research. Conclusions will be drawn as a result of the findings, and recommendations concerning how the research can be used to aid in curricular scheduling and sequencing in the future will also be made.

CHAPTER II

REVIEW OF LITERATURE

Chapter II of this study is the Review of Literature. Within this chapter are found sections concerned with modern educational systems from a global perspective, integrating mathematics and technology instruction, a mathematics instructional paradigm, and programs currently utilizing new approaches to educating American youth.

Modern Educational Systems - A Global Perspective

In contrast to the practical educational systems of Europe and Japan, American schools have failed to require students who are not college bound to enroll in technical or apprenticeship programs that appropriately mix learning and work. Vocational and technical education for years has been responsive to employers' specific needs. Generally, training concentrated on teaching about techniques for specific tasks. Many students,

however, enter and leave vocational education programs with poor academic skills; few achieve the academic foundation needed in a fast-changing technological society. Apt and teachable students who find the classic baccalaureate curriculum a waste of time and effort and vocational education ineffective in preparing them for technically elite jobs fall through the cracks in our education systems.

In a typical high school, about one third of the students are seriously preparing to enter baccalaureate programs. Their program of study, often known as college prep, prepares them for professional or semiprofessional careers. Another third of the students, because of interest or need, will complete their formal education before or at graduation from high school and immediately enter the work force. This group needs a well-designed appropriately structured vocational education program. The remaining high school students are enrolled in an unfocused program usually called general education. Most often, unfortunately, this curriculum fails to either engage students' interest or to prepare them adequately for work or further education. This group represents the two middle quartiles of a typical high school population. In other words, the average student. This represents an untapped potential for enabling our

country to regain its competitive edge in world markets.

Many such students perform poorly in school because they do not learn well in the abstract; they are hands-on learners. A curriculum of applied academics can make learning understandable, achievable, and attractive for hands-on learners. Applied academics in math, science, and communications form a foundation of knowledge, a core curriculum, which will help students understand complex technologies and new skill requirements in the work environment. Regardless of the field, most jobs that offer growth, challenge, and earning potential require a working knowledge of math, technical principles, and communications skills. Well-educated workers can transfer their knowledge of basic principles and technologies to practical applications in a variety of technical jobs (Hull, 1992, p. 17).

Unfortunately, contemporary instructional strategies often do not provide many students with a clear understanding of key concepts being taught. Because of the abstraction inherent in mathematics, the teaching of it in school tends to be authoritarian everywhere. It is much easier to present students with the "rules" to be accepted without question, than more helpfully, to explain that the architecture of mathematics is based on accepted axioms and on theorems obtained by logic. This situation seems strange

indeed, since the evolution of western mathematics stems essentially from the glorious Greek culture, a source of our democratic ideals that is over two thousand years old. The adherence to democratic ideals within the mathematics classroom can confuse students undergoing traditional authoritarian instruction. This often results in making learning difficult for students. The only reason it does not create the particular difficulties abroad that we encounter in the United States is that almost all the countries in the world either have lived until recently under authoritarian regimes or still do so. Even most democratically governed countries have maintained an authoritarian approach in the family and schools.

In the United States the concept of democracy is so basic to our way of life that it has permeated family and schools. We assume on the basis of our democratic faith that we all have the right to an equally valued vote. This equality we believe, must be extended as far as possible, even to intellectual fields, where obviously it does not apply. After all, some of us are less intelligent than others. Hence, while courses in social studies, history, the humanities in general, can be taught in a fairly democratic way, mathematics and much of science are presented with an authority that does not admit objections. In fact, if taught

more honestly, mathematics teaching could accommodate questioning and doubts by explaining the conventionality of axioms, the rudiments of logic and the levels of abstraction. Our students instead, listen to the humanity teachers explaining our democratic political faith and simplify it with the statement: "We are all equal." Then these students go to the next room and, in answer to the question "Why is plus times minus, minus and minus times minus, plus?" Hear the math teacher answer with infallible authority: "This is a rule. Just do it and do it my way or I will mark it wrong." Or, more classically, when questioning the "rule" for the division of fractions: "Yours is to invert and multiply, and not ever to ask why" (Salvadori, 1991, p. 43).

Science and math are of course the foundations of technology, so those results have to portend a decline in our national technical competence. Technology is what drives home the importance of science and math, and a failure to include technology throughout the K-12 curriculum for all students is at least partly to blame for the low science and math interest and achievement of the majority of our students. It's the applications of science that fire the imaginations of most students. Unfortunately, due to an odd kind of snobbishness, we too often teach science and math with little attention to applications. The nation is the

worse for this omission (McClelland, 1992, p. 1).

American education stands at a crossroads. As American young people fall farther and farther behind their peers in other countries, a broad consensus is building for the need for change. Nowhere is this concern in greater evidence than among our major corporations, which today are hiring a high percentage of foreign born scientists and engineers. Particularly in our research-based companies, there is a growing concern about the lack of well educated, well trained, American young people.

Part of the solution must certainly be to refocus classroom activity from the teacher to the student. Child centered learning, peer tutoring, problem solving, and activity based learning are all promising new directions worthy of exploration. Unfortunately, these approaches are currently all too rare in our schools; indeed, the major outposts of activity-based learning are art, music, and technology education. All too often these courses are considered mere electives, interesting enough for those who choose to pursue them, but of no fundamental importance.

Technology educators, unconstrained by the need to prepare students for advanced placement tests, place strong emphasis on project-based learning, on tinkering and experimentation, and on group learning. The skills that most of us

use every day in our real world jobs. As a result, technology education has a real chance to develop successful models that can be transported back to education in general. To date this has not happened, partly because technology education is not yet taken seriously as a discipline of critical importance to all educated people. The time is ripe for innovation and change, and an opportunity now exists to make a real impact (Howarth, 1993, p. 1).

However, academic teachers teach for the college bound. Guidance counselors counsel for the college bound. A student who is not college bound is thrown into a "second rate" program called vocational education. Society and the educational system have deprived a large portion of the population a chance to be successful. The real problem is that our system has given only a small percentage of the population a college education. The real problem is that our society has undereducated a larger percentage of the population to the point that many citizens are nearly dysfunctional in an increasingly technological world. The typical high school graduate who concentrates course work in the general education track leaves high school with limited academic preparation and no technical skills. Such graduates are not prepared to work in a technological society. Furthermore, rarely

do they earn anything more than minimum wage, and they are not capable of making the transition into post secondary education.

Educators must decide if it is better to educate the majority of students or only a small minority. To adequately educate the majority will mean that the methods that have been in use for decades must change. We must develop and test methods that address all students, methods that incorporate applied learning strategies and activities relevant to today's world. The best way to accomplish this is to infuse academic subject matter with technical subject matter in such a way that each discipline reinforces and builds upon the other. Integrating academic and technical subject matter is a major change for teachers. For this change to occur, educational leaders must adequately address the barriers that impede it (Cahill, 1993, p. 17). We need new mathematics, science, and technology programs that are integrated and based on contextual learning. Students need to learn that seemingly unrelated events or observations can be understood by applying generic concepts that come from the study of mathematics, science, or technology (Liao, 1993, p. 19). This application of concepts is valuable at all grade levels. Teaching science and mathematics in early grades forms a foundation for further study and determines whether or not a young person will become

"science literate" as a citizen, let alone a future scientist or engineer. At the middle and high school levels, teachers are simply cut off from the scientific community and have few opportunities to update their knowledge. These teachers are frequently unable to apply the basic mathematical and scientific concepts they teach to real-life situations (Stephens, 1992, p. 1).

The real challenge for American education is to provide improved foundational education in basic skills: reading, writing, language, mathematics, communication, problem solving, and reasoning. This is especially urgent for disadvantaged youth who have serious learning disabilities. We must reevaluate the role of vocational education in American education and reassess current high school curriculum to meet the challenges of global competition (Ryan, 1992, p. 36).

Integrating Mathematics and Technology Instruction

Students do not understand that concepts that they learn in subjects like math relate to the world of work. They are not being taught many of the things they need to know to pursue good and rewarding careers.

In the past, businesses have not done a good job telling educators what skills they need and want. Consequently, while

most teachers can tell what students must learn to be prepared for college, few can tell you what students need to know and be able to do to get a good job. Students have no idea either.

The world has changed dramatically. Nobody today can avoid technology. Those unable to use it face a lifetime of menial work. Consequently, all students need to learn more about technology. They must be able to select and use appropriate technology, visualize operations, monitor tasks, and maintain complex equipment (Brook, 1992, p. 5). Employers usually expect schools to have trained their workers. They are concerned that their workers understand such concepts as Ohms law and wiring diagrams, using common tools, and applying problem-solving skills when they focus on entry-level requirements for skilled jobs. Insofar as schools do not adequately train workers for the work force, taxpayers spend much more to have other agencies do it. Furthermore, as the situation presently stands, many jobs do not require a college education. This in itself warrants that students should not study academic subjects to the near exclusion of industrial/vocational education (Stadt, 1991, p. 30).

Education develops the capacity of individuals to explore and elaborate our relationship with the surrounding world. It should excite us about doing so. In our teaching, it is essential to

seek ways of revealing connections to real world applications. Our world is a result of a complex interplay of conditions only partially described by any one discipline. We need to demonstrate how the various disciplines to which students are introduced represent different perspectives on the same world.

Educational problem-solving which speaks clearly to the web of relationships constituting our experience are critical to contemporary youngsters. In all strata of our society we see evidence of alienation, a breakdown of basic institutions. On the other hand, we are called upon to accept increasing responsibility for the impact of our actions on our immediate neighborhoods and on the larger community.

Technology education in particular has much to offer. Design problems begin with desire, that is, the will or wish to change, enhance, or refine some aspect of our circumstances. The design process demands that we pursue a solution within the context in which it must unfold; that we take into consideration the related conditions, which can be physical, social, economic, political, environmental, and more. It asks us to connect the knowledge of various disciplines to an experience of the world at large (Kriegh, 1992, p. 39). The vocational track represents a chance for many talented students to get a jump on the kind of

career whose future is assured (Hacker, Van Dyke, and Binder, 1992, p. 11).

Applied to schooling, it is easy to see that information age technologies put us in a much better position than ever before to accommodate individual needs, individual learning styles, and individual preferences. But to take advantage of this power to customize, we must change the predominant structure of schooling in America. It still functions as an institution of mass production.

In the future, technological resources will mark the difference between the haves and the have-nots. Those with resources will have choices and educational advantage. If schools are not to be left behind, they must move now to tap the power of technology. To do so, schools must be willing to change. They must recognize they are no longer the sole source for education, and they must be willing to promote a broader range of educational options to the communities they serve (Kinnaman, 1994, p. 74).

By becoming more flexible, technology education is able to integrate closely with instruction in math, science, and communication. Such an emphasis brings technology education closer to the central focus of education and decreases its

tendency to be viewed as an isolated, separate subject. In contrast, the danger of making a given activity a permanent part of a curriculum is that it becomes just another process. Standard exercises are isolated and subject to obsolescence. They may also lead to the diminution of the application of creative problem solving and critical thinking. It is important to remember that curricula must be flexible and easily adjustable to accommodate rapid technological change. One of the important concepts that the technology education curriculum conveys to students is the adaptability of the systems approach to solve problems rather than to produce artifacts or go through repetitive processes. Curricula should, then, focus on ways of teaching problem solving, critical thinking, and group interaction. In this time of change, both teachers and students should remain flexible and be willing to adopt new ideas (Baker and Householder, 1992, p. 15).

A Mathematics Instructional Paradigm

All people need mathematical skills in every day living. Many men and women use specific mathematical skills in their work, none of whom would be regarded as mathematicians. These people were applying mathematical concepts, knowledge, and skills to a task and using math as a form of communication.

Capability in the workplace requires a range of operational skills including mathematics that can be termed broadly as design. Unfortunately, design skills are not basic in the educational system though many of the necessary skills for designing are enveloped in higher order thinking programs and in the arts and technology disciplines (Bottrill, 1992, p. 34).

In today's complex and fast changing world, it's clear the future will be increasingly shaped by problem solvers who are schooled in the various technical fields. Chemistry, mathematics, physics, science, and engineering, these disciplines are the real resources that will enable us to grow our nation's economy and sustain our quality of life. Through technology education, these resources can be realistically applied to the workplace (Derr, 1993, p. 2).

The ideal mathematics classroom must be a mathematical community where the students and the teacher talk the language of math; work in groups to solve open-ended, real world problems; use calculators, manipulatives, and computers intelligently; and verify their answers together, using mathematical reasoning rather than an answer key. Standardized tests emphasizing rote drill and practice skills are a major stumbling block, in part because they strongly influence what and how teachers teach. But the

movement from a traditional textbook centered course to a more free flowing, open ended course is happening, and a large number of states are revising their curriculum framework to reach new standards (Eiser, 1993, p. 52).

Many students realize that technical math is a necessary evil to get a job done; it's not exactly fun. But as equipment and techniques become more sophisticated, they must have math skills. Many in industries emphasize basic math skills in workplace training programs.

Many a poor or uninterested student in the past has been snatched from the jaws of math boredom by the practicality of applied math. Fractions are certainly more relevant when you are holding a $\frac{3}{8}$ inch socket to a $\frac{1}{4}$ inch nut (Granger, 1993, p. 22). The teaching of mathematics and physics at the elementary and junior high levels can be greatly facilitated by a hands-on approach which employs experiments and model-making (Salvadori, 1991, p. 43). More advanced students can use conventional trigonometric and algebraic methods. Once these levels of mathematical understanding have been achieved graphic analysis will be appropriate for most students throughout high school instruction (Karsnitz, 1993, p. 25).

Educators must also be willing to train girls as well as boys

in vocational programs. This has typically not been the case, and as a result, girls who have been excluded from high school application-based technological programs have failed to develop skills in mathematics at an acceptable rate as have high school boys. Math performance among girls is basically equal to math performance among boys until about age 13, when girls' performance begins to falter (Husher, 1993, p. 15).

Teachers can make trigonometry more than an abstract exercise by relating it to the operation of a computerized milling machine. Students in work-based learning programs are more likely to stay in school because their lessons are more interesting and more relevant to what they are expecting to do in the future. They see the connections between learning and earning; they get a better understanding of the demands of the workplace and are better prepared to succeed in it (Reich, 1994, p. 1). In the process of building the bridge, students learn to understand and use design, construction, and engineering principles; transferable knowledge that can change the way they interact with the world around them (Cooper-Hewitt Museum Staff, 1991, p. 6). With adequate opportunity to utilize mathematical tools within application-based instructional activities, students will become better problem solvers. Some of these mathematical tools allow

students to use calculations to find physical solutions to problems specific to hands-on activities, others use simplified statistical procedures to generate data, and others display data or information in various forms for further analysis. Each can be applied to a variety of design and problem solving situations (Alexander, 1993, p. 21).

Vocational education can serve as a context for teaching academics. If applied math, communications, science, and other skills are intentionally emphasized in appropriate vocational courses, these skills will suddenly have a purpose apart from the grade or credit (Rankin, 1993, p. 15).

Programs In Action

Throughout America, pilot programs are being developed which allow students to apply mathematical, scientific and technological concepts within activity-based instructional activities. Project Update, funded by the National Science Foundation, has set out to design and develop curriculum materials and guidelines for generating, sharing, and assessing integrated S/M/T (science, mathematics, and technology) activities suitable for and interesting to all children K-8 (Todd, Doyle, and Hutchinson, 1993, p. 51).

During the last five years, hundreds of teachers in Boston Public Schools have observed the positive impact of technology on their students' ability to learn, especially in the area of mathematics. Each teacher involved in the Elementary and Middle School Math and Technology Project, which is funded by the National Science Foundation and Boston Public Schools, received two computers, a calculator and "hands-on" math materials for their classrooms. Coupled with intensive workshops in mathematics and new strategies for teaching math (cooperative learning, interdisciplinary teaching, etc.), these materials have provided rich and vastly different learning experiences in math for Boston students. All lessons involve the teaching of concepts, not techniques for getting answers. Students engage in problem solving while working in groups and sharing ideas and knowledge. Computers are used as tools to reinforce or check skills work, and students find it easy to engage in more complex problem-solving projects (Bingaman, Kennedy, and Cochran, 1993, p. 3).

In response to the problem of students not having the opportunity to acquire engineering related skills in school, East Bay High School in Gibsonton, Florida, has introduced a curriculum designed to give students true-to-life engineering

experiences. The program is getting rave reviews from college-bound students. Juniors and seniors who have set their sights on engineering careers now place Engineering Technology at the top of their scheduling priorities. Students are recruited through faculty presentations while they are in their physics and chemistry classes (Binder, 1992, p. 10).

Students enrolled in vocational education courses at Tynehead Elementary School, in British Columbia, research clothing worn 100 years ago and create drawings of garments of that time. What began as a history lesson quickly became a series of math problems as students calculated dimensions in their drawings (Markland, 1991, p. 35).

In high school throughout northern New York State, the Principles of Engineering curriculum has provided a setting for students to apply scientific principles, mathematical skills, and knowledge, and an interest in engineering in an unprecedented simulation of industry in their schools (Agoglia, 1992, p. 10).

At Forest High School in Oak Park, Illinois, chemistry and physics technical classes use an applicative learning strategy as a vehicle for mainstreaming and increasing a student's curiosity in science and math in a climate that promotes critical thinking, learning by discovery, and cooperative learning. Technology

activities become the platform for science where students integrate algebra, geometry, trigonometry, or statistics into solving real world problems. Technology provides a framework for science that supports and enhances the wide range of concepts studied in chemistry and physics. Mathematics, the principle "servant to science", is an integral component of unified science technology activities (Gauger, 1992, p. 50).

Summary

There has been considerable research done concerning the problem solving abilities of American high school students. Much of the information gained from initiating problem-solving activities within high school curricula seems to suggest that a firm foundation of basic mathematical skills greatly improves the problem-solving abilities of students.

There are many reasons that American high school graduates lack well defined problem-solving abilities. One major flaw found within many American educational systems has been seen as a contributing factor to this enigma. It has been found that the tracking of students allows for the shortchanging of millions of youngsters who are, somehow, judged to be not good enough for the college prep track. The very existence of vocational education

programs allows schools to do less than the best for all students. In many school systems, vocational education programs are used as dumping grounds. These classes are for youngsters seen as not capable of making it in more challenging courses.

Some educators are now seeing problems with this tracking method. First, recent government studies have pointed out a need for schools to increase graduation requirements in basic subjects, and encouraged vocational educators to look for ways to give credit for work covered in vocational classes. Second, funding sources have started to require the integration of vocational and academic skills. Third, the work roles for which vocational teachers prepare students have increasingly greater intellectual demands. Students now have to know how to use their hands and their heads. Fourth, and most distressing, is the failure of academic instruction to provide vocational programs with properly educated students. In response, vocational programs have had to sacrifice time to beef up academics that students should have gained elsewhere.

For vocational teachers, math is not a spectator sport. Vocational instructors favor approaches that mathematics curriculum reformers have only recently embraced: more calculators, less memorization, more study and research skills

development, using a project approach, and cooperative education strategies.

Math teacher's emphasis on skills and drill has made their students somewhat successful in computational performance, and this satisfies the teacher's accountability burden. However, the student's ability to transfer conceptual skills to problem solving situations seems nonexistent.

Although the trend for vocational programs, out of necessity, is to move toward greater cooperation with academic subjects, vocational education has more to offer to academic teachers than vice versa. Vocational education shows how hands-on experiences inform and enlighten the mind and its understanding.

Things that are intrinsically interesting are easier to learn, and more meaningful, than things that aren't. The usefulness of something often makes it interesting. Vocational students study things that capture their attention. Vocational education can put life back into mathematics, and perhaps other academic subjects as well. It can bridge the gap between the real world and the academic world, provide the kind of well educated work force business and industry need, and play a significant role in helping to make us less of a nation at risk (McGhan, 1992, p. 33).

CHAPTER III

METHODS AND PROCEDURES

Chapter III of this study is called Methods and Procedures. Within this chapter are found sections concerned with the population and sub-populations used in this study, the research variables of the study, the design of the instrument used in this study, methods used in data collection, methods of statistical analyses, and an overview of this study's methodologies.

Population

The target population of the study are male and female students in grades nine through twelve at Churchland High School in Portsmouth, Virginia. Churchland High School serves both inner-city and suburban populations with lower to upper socioeconomic backgrounds. Students were randomly selected

from technology education and mathematics classes with no regard to their gender, present grade levels, or socioeconomic backgrounds. However, there was considerable regard given to the quantity of previous mathematical experiences had during high school instruction.

The total sample size included in this study is sixty students. All of the students were divided into twenty, homogeneous and heterogeneous three-person teams. Five of the homogeneous teams contained three students, each having had already completed one thirty-six week course in mathematics. Five of the homogeneous teams contained three students, each having had already completed two thirty-six week courses in mathematics. Five of the homogeneous teams contained three students, each having had already completed three thirty-six week courses in mathematics. There were also five heterogeneous teams included in the study as a control group. Each of these three-member teams contained one student who had already completed one thirty-six week course in mathematics, one student who had already completed two thirty-six week courses in mathematics, and one student who had already completed three thirty-six week courses in mathematics. All of the students took the same mathematics courses, in the same sequence.

Research Variables

Research variables include variations in the information covered within the realm of math courses and technology courses taken by students. Although there are some differences in instruction from one class to another, it was assumed these differences to be inconsequential.

Course offerings in mathematics are offered within a comprehensive program which provides the opportunity for college and vocational preparation. The sequence that students participating in this study are taking is: Algebra 1, Geometry, and Advanced Algebra/Trigonometry.

The Algebra 1 curriculum is concerned with a modern treatment of basic ideas and the structure of algebra. Topics introduced to students include: the number line, sets, variables, open sentences, positive and negative numbers, absolute value, equations, inequalities, polynomials, factoring algebraic fractions, coordinates in a plane, graphing of truth sets and equations and inequalities, irrational numbers, and the real number variation and quadratics.

The Geometry curriculum integrates elements of plane, solid, and coordinate geometry. Concepts of space are developed and related to the plane. Algebra and geometry are extended in

the coordinate plane. Emphasis is placed on the application of logic in every day situations. Methods of proof needed for further study of mathematics are employed.

The Advanced Algebra/Trigonometry course continues the study of algebra and introduces trigonometry demonstrating the interdependence of real and complex numbers and their functions. It places emphasis on application to other sciences, establishes a firm foundation for the study of calculus, encourages mathematical reasoning, develops sophistication on the part of the student in exploring the structure of mathematics, and improves skills in algebraic manipulations. Computer applications of mathematics are also presented.

Concepts learned by students in venues other than school will also vary from student to student. However, considering the student's age and background, these differences are considered minuscule.

Students used in this study ranged in age from 13 to 20. They have been studying mathematics and technology in multi-aged classes. There existed developmental differences in the students learning techniques.

Instrument Design

The instrument used in gathering research data for this study is produced by Pitsco, Incorporated, of Pittsburg, Kansas. The bridge building competition rules were developed with the input of various Technology Student Association competition results. Each team package included the following written materials: a curriculum guide, bridge construction directions, competition rules, evaluative tests, and graph paper for design and engineering drawings. Each team package also included the following building materials: fifteen pieces of basswood, each measuring $\frac{3}{16}$ inch by $\frac{3}{16}$ inch by twenty-four inches long and two ounces of polyvinyl resin glue in a squeeze bottle. Students had access to hobby knives, model saws, pins, tape, and sandpaper to work the materials into various shapes.

Testing apparatus included two square tables of the same height spaced ten inches apart, a one inch by one and a half by an eight inch rectangular-test block with a one quarter inch hole drilled through the center of its largest surfaces, a one quarter by six inch eye-bolt, washer, and nut, a five gallon plastic bucket, and various sized weights.

This activity has been used throughout the nation in high school technology laboratories during instructional activities. It

has been developed to provide students that have had previous mathematics experience with application of mathematical-concepts taught in school. It is used to determine and evaluate pre-engineering capabilities of high school students. The depth of the displayed quality of workmanship, attention to detail, creative and logical design, and commitment to excellence are determined to suggest the probable depth of any individual student's pre-engineering capabilities.

Laboratory Procedures

Students worked within three-member teams which were randomly selected from various predetermined sub-populations. The students first received both traditional and hands-on instruction relating to trigonometric formulas, measuring, calculating scales, structural engineering, the history of bridge engineering, contemporary bridge construction, model building techniques, tool usage, data acquisition, processing, and record keeping, and laboratory safety. Mathematical concepts concerning linear measurement in inches, feet, and miles was introduced in word problems directed toward the development of models and actual structures. Students were also given instruction as to how to calculate scale measurements in models and in drawings.

Students used algebraic formulas to calculate the areas of various triangles. They also used the Pythagorean Theorem to calculate the length of the sides and the length of the hypotenuse of various right triangles. Students also used mathematical computation to calculate various weights of loads in metric and standard weights in word problems related to engineering and construction. These mathematical concepts were introduced and reinforced during instructional activities such that the applications of concepts being taught were apparent. Teams met for fifty-eight minutes per day, and constructed their bridge models for fifteen days.

When the bridge models were completed, destructive testing was initiated. Bridges were placed one at a time across a ten inch span, from table top to table top. The rectangular test block was then placed centrally on the bridges roadway. The eye bolt was then placed upward between bridge members from underneath the substructure and roadway, through the test block, and secured in place with a washer and nut. A five gallon bucket was then hung from the eye bolt. The bucket was filled with increasing amounts of weight at ten second intervals until structural failure resulted and structural members were fractured. The bridge-testing apparatus used is shown in Figure 1.

BRIDGE TESTING APPARATUS

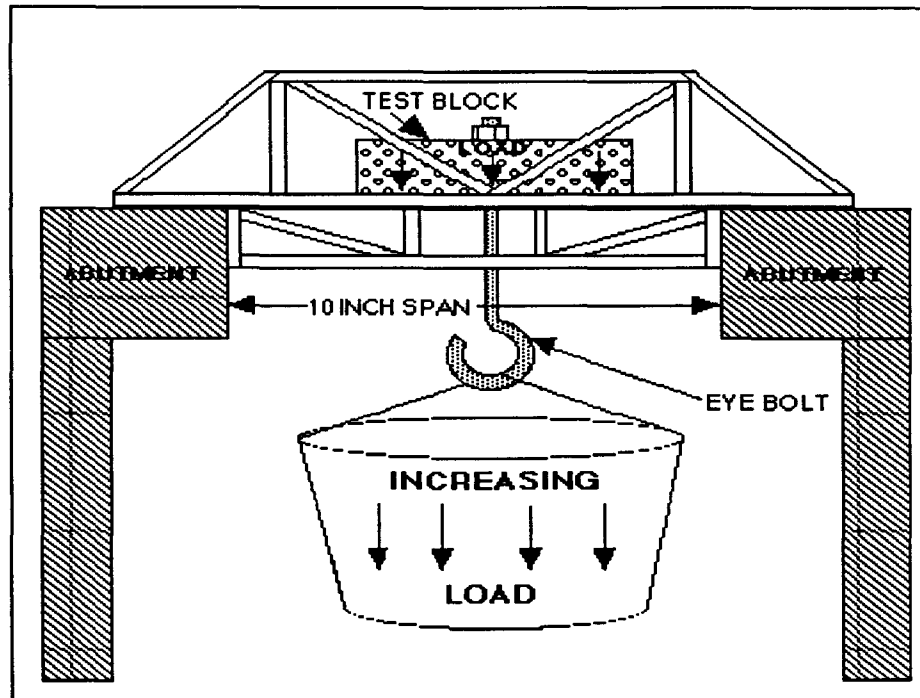


Figure 1

Methods of Data Collection

Weights were recorded and added as they were placed into a bucket, which was suspended from the test block, now held within the bridge superstructure. Ten seconds was allowed to pass between load additions in order to allow the bridge models to undergo deformation and eventually failure under increasing loads. Failure loads were recorded.

The efficiency levels of each bridge model was calculated during this study in order to ensure appropriate results.

Allowances for slight differences in the quantity of materials used by each group were made. This helped students to concentrate on structural design qualities instead of a mass-equals-strength relationship in model designs.

The mean efficiency level of all bridge models was determined. Efficiency levels were then placed within their appropriate heterogeneous and homogeneous subgroups, developed according to the number of thirty-six week mathematics courses completed by each team member. The data was then further analyzed and relationships between the quantity of mathematics instruction completed by each student and the quality of their engineering designs were established.

Statistical Analysis

In order to determine efficiency rates of models the following formula was used:

$$\text{efficiency level} = \frac{\text{weight of load at failure (lbs.)} \times 4.45}{\text{weight of bridge (g.)}}$$

This formula allows for slight differences in materials used by each group and helped concentrate on structural design qualities instead of a mass-equals-strength relationship in model designs.

A series of t-Test analyses were then conducted in order to

determine if there was a relationship between each of the homogeneous group scores and the scores of the heterogeneous-control group. The following t-formula was used:

$$t = \frac{M_1 - M_2}{\sqrt{\left(\frac{\sum d_1^2 + \sum d_2^2}{N_1 + N_2 - 2} \right) \left(\frac{N_1 + N_2}{N_1 N_2} \right)}}$$

Summary

The instrument used for the research, designed by Pitsco, Incorporated, will help to determine the problem-solving abilities of high school students with varying mathematical backgrounds. Using the results of tests performed, it may be determined which groups of students designed better engineered structural models.

Once it has been determined which groups designed and built better structures, conclusions can be drawn. In Chapter IV of this study, test scores and research findings will be presented.

CHAPTER IV

FINDINGS

In Chapter IV the Findings of this study are presented. The study's purpose, to compare the problem-solving abilities of high school students with varying degrees of mathematics instructional backgrounds, was accomplished using a commercially available design and model building kit.

The research instrument used in gathering research data for this study is produced by Pitsco, Incorporated, of Pittsburg, Kansas. The bridge building competition rules were developed with the input of various Technology Student Association competition results. This activity has been used throughout the nation in high school technology laboratories during instructional activities. It is used to determine and evaluate pre-engineering capabilities of high school students. The depth of the displayed quality of workmanship, attention to detail, creative and logical

design, and commitment to excellence are determined to suggest the probable depth of any individual student's pre-engineering capabilities.

Reporting of Data

The five homogeneous groups of three students, each having taken one year of mathematics, produced the following results. Group number one built a bridge model that weighed 14 grams. It was not long enough to span the ten inch testing-gap and therefore was not able to withstand any load. The efficiency of group number one's bridge model was 0.0. Group number two built a bridge model that weighed 20 grams that withstood a load of 3.2 kilograms. The efficiency level of that bridge was 1.6. Group number three built a bridge model that weighed 20 grams that withstood a load of 6.8 kilograms. The efficiency level of that bridge was 3.3. Group number four built a bridge model that weighed 16 grams that withstood a load of 0.9 kilograms. The efficiency level of that bridge was 0.6. Group number five built a bridge model that weighed 8 grams that did not span the ten inch testing-gap and therefore was not able to withstand any load. The efficiency level of that bridge was 0.0 (see Table 1).

Groups of Students With One Year of Mathematics Courses

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
1	1	14 grams	0.0 killos	0.0
2	1	20 grams	3.2 killos	1.6
3	1	20 grams	6.8 killos	3.3
4	1	16 grams	0.9 killos	0.6
5	1	8 grams	0.0 killos	0.0

Table 1

The five homogeneous groups of three students, each having taken two years of mathematics, produced the following results. Group number six built a bridge model that weighed 27 grams that withstood a load of 11.4 kilograms. The efficiency level of that bridge was 4.1. Group number seven built a bridge model that weighed 22 grams that withstood a load of 5.5 kilograms. The efficiency level of that bridge was 2.4. Group number eight built a bridge model that weighed 28 grams that withstood a load of 27.3 kilograms. The efficiency level of that bridge was 9.5. Group number nine built a bridge model that weighed 13 grams that withstood a load of 3.2 kilograms. The efficiency level of that bridge was 2.4. Group number ten built a bridge model that weighed 28 grams that withstood a load of 16.8 kilograms. The efficiency level of that bridge was 5.9 (see Table 2).

Groups of Students With Two Years of Mathematics Courses

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
6	2	27 grams	11.4 kilos	4.1
7	2	22 grams	5.5 kilos	2.4
8	2	28 grams	27.3 kilos	9.5
9	2	13 grams	3.2 kilos	2.4
10	2	28 grams	16.8 kilos	5.9

Table 2

The five homogeneous groups of three students, each having taken three years of mathematics produced the following results. Group number eleven built a bridge model that weighed 24 grams that withstood a load of 6.8 kilograms. The efficiency level of that bridge was 2.8. Group number twelve built a bridge model that weighed 25 grams that withstood a load of 5.5 kilograms. The efficiency level of that bridge was 2.1. Group number thirteen built a bridge model that weighed 30 grams that withstood a load of 11.4 kilograms. The efficiency level of that bridge was 3.7. Group number fourteen built a bridge model that weighed 23 grams that withstood a load of 9 kilograms. The efficiency level of that bridge was 3.9. Group number fifteen built a bridge model that weighed 22 grams that withstood a load of 14.5 kilograms. The efficiency level of that bridge was 6.5 (see Table 3).

Groups of Students With Three Years of Mathematics Courses

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
11	3	24 grams	6.8 kilos	2.8
12	3	25 grams	5.5 kilos	2.1
13	3	30 grams	11.4 kilos	3.7
14	3	23 grams	9.0 kilos	3.9
15	3	22 grams	14.5 kilos	6.5

Table 3

The five heterogeneous groups of three students, one having taken one year of mathematics, one having taken two years of mathematics, and one having taken three years of mathematics produced the following results. Group number sixteen built a bridge model that weighed 28 grams that withstood a load of 18.2 kilograms. The efficiency level of that bridge was 6.4. Group number seventeen built a bridge model that weighed 29 grams that withstood a load of 34.1 kilograms. The efficiency level of that bridge was 11.5. Group number eighteen built a bridge model that weighed 23 grams that withstood a load of 16.8 kilograms. The efficiency level of that bridge was 7.2. Group number nineteen built a bridge model that weighed 22 grams that withstood a load of 7.7 kilograms. The efficiency level of that bridge was 3.4. Group number twenty built a bridge model that weighed 27 grams that withstood a load of 11.4 kilograms. The efficiency level of that bridge was 4.1 (see Table 4).

**Groups of Students- Each Having One, Two,
or Three Years of Mathematics Courses**

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
16	1,2,&3	28 grams	18.2 kilos	6.4
17	1,2,&3	29 grams	34.1 kilos	11.5
18	1,2,&3	23 grams	16.8 kilos	7.2
19	1,2,&3	22 grams	7.7 kilos	3.4
20	1,2,&3	27 grams	11.4 kilos	4.1

Table 4

The efficiency levels of the five homogeneous groups made up of three students, each having had one year of mathematical classes were 0.0, 1.6, 3.3, 0.6, and 0.0. The mean efficiency level of these groups is 1.1 (see Table 5).

MEAN EFFICIENCIES OF GROUPS WITH ONE YEAR OF MATHEMATICS COURSES

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
1	1	14 grams	0.0 kilos	0.0
2	1	20 grams	3.2 kilos	1.6
3	1	20 grams	6.8 kilos	3.3
4	1	16 grams	0.9 kilos	0.6
5	1	8 grams	0.0 kilos	0.0
Homogeneous Groups With 1 Year of Mathematics- Mean Efficiency = 1.1				

Table 5

The efficiency levels of the five homogeneous groups made up of three students, each having had two years of mathematical

classes were 4.1, 2.4, 9.5, 2.4, and 5.9. The mean efficiency level of these groups is 4.9 (see Table 6).

MEAN EFFICIENCIES OF GROUPS WITH TWO YEARS OF MATHEMATICS COURSES

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
6	2	27 grams	11.4 kilos	4.1
7	2	22 grams	5.5 kilos	2.4
8	2	28 grams	27.3 kilos	9.5
9	2	13 grams	3.2 kilos	2.4
10	2	28 grams	16.8 kilos	5.9
Homogeneous Groups With 2 Years of Mathematics- Mean Efficiency = 4.9				

Table 6

The efficiency levels of the five homogeneous groups made up of three students, each having had three years of mathematical classes were 2.8, 2.1, 3.7, 3.9, and 6.5. The mean efficiency level of these groups is 3.8 (see Table 7).

MEAN EFFICIENCIES OF GROUPS WITH THREE YEARS OF MATHEMATICS COURSES

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
11	3	24 grams	6.8 kilos	2.8
12	3	25 grams	5.5 kilos	2.1
13	3	30 grams	11.4 kilos	3.7
14	3	23 grams	9.0 kilos	3.9
15	3	22 grams	14.5 kilos	6.5
Homogeneous Groups With 3 Years of Mathematics- Mean Efficiency = 3.8				

Table 7

The efficiency levels of the five heterogeneous groups made up of three students, each having had either one year of mathematical classes, two years of mathematical classes, or three years of mathematical classes were 6.4, 11.5, 7.2, 3.4, and 4.1. The mean efficiency level of these groups is 6.5 (see Table 8).

**MEAN EFFICIENCIES OF GROUPS WITH ONE, TWO,
AND THREE YEARS OF MATHEMATICS COURSES**

Group Number	Years of Mathematics	Weight of Bridge	Load Withstood	Bridge Efficiency Level
16	1,2,&3	28 grams	18.2 kilos	6.4
17	1,2,&3	29 grams	34.1 kilos	11.5
18	1,2,&3	23 grams	16.8 kilos	7.2
19	1,2,&3	22 grams	7.7 kilos	3.4
20	1,2,&3	27 grams	11.4 kilos	4.1
Heterogeneous Groups With 1, 2, & 3 Years of Mathematics- Mean Efficiency = 6.5				

Table 8

Figure 2 graphically demonstrates the differences in the efficiency levels of the three homogeneous experimental groups compared to the heterogeneous control group.

COMPARISONS OF MAJOR GROUP EFFICIENCY LEVELS

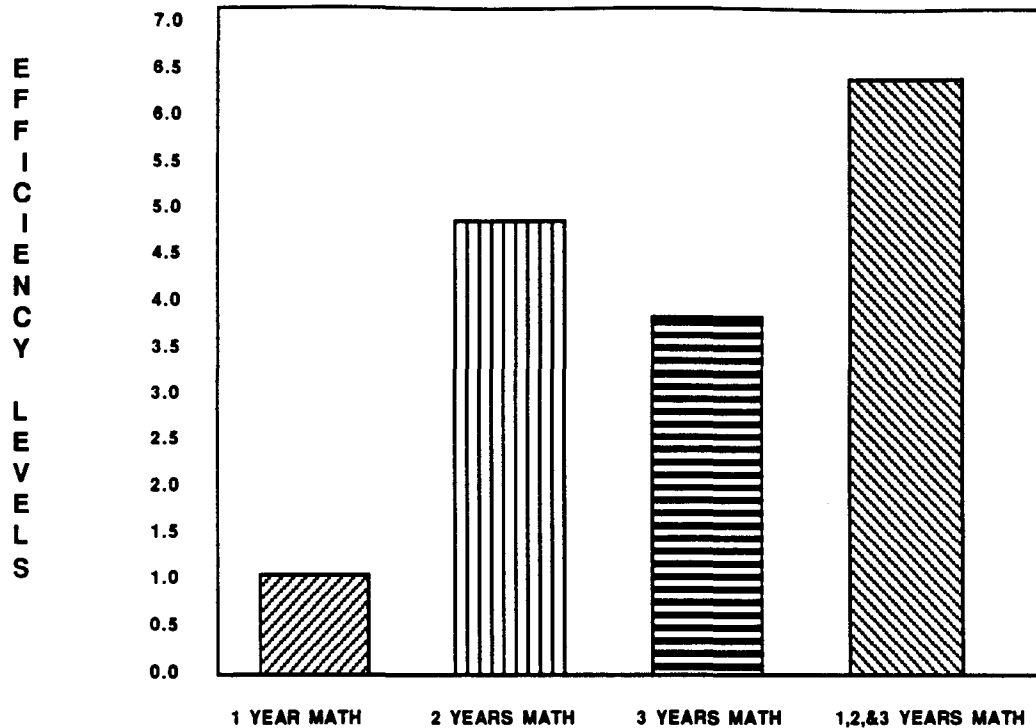


Figure 2

STATISTICAL T-TEST CALCULATIONS

In order to effectively evaluate the scores from the four major groups of students, the mean of the scores from each of the five sub-groups within each of the four major groups were used. The mean score for the heterogeneous control group was compared to the mean scores of each of the homogeneous groups using the statistical *t*-test method.

The resulting calculation from the *t*-test comparing the homogeneous group of students that have taken one year of

mathematics courses to the heterogeneous group was -1.16. This value is significant at the $p=.05$ level, concluding that the performance of the control group was superior to that of the group with one year of mathematics instruction (this number is an estimated value found by calculations compared to The Oliver and Boyd Table II *CRITICAL VALUES OF t^**).

The resulting calculation from the t -test comparing the homogeneous group of students that have taken two years of mathematics courses with the heterogeneous group was .28. This value is significant at the $p=.05$ level, concluding that the performance of the control group was superior to that of the group with two years of mathematics instruction (this number is an estimated value found by calculations compared to The Oliver and Boyd Table II *CRITICAL VALUES OF t^**).

The resulting calculation from the t -test comparing the homogeneous group of students that have taken three years of mathematics courses to the heterogeneous group was .51. This value is significant at the $p=.05$ level, concluding that the performance of the control group was superior to that of the group with three years of mathematics instruction (this number is an estimated value found by calculations compared to The Oliver and Boyd Table II *CRITICAL VALUES OF t^**).

In order to determine a relationship between performance levels of each of the homogeneous groups of students, the mean scores from each of the five sub-groups within the two-year mathematics and three-year mathematics homogeneous groups were compared with the mean score from each of the five sub-groups within the one-year mathematics homogeneous group.

The resulting calculation from the *t*-test comparing the one-year mathematics groups and the two year mathematics groups was -1.08. This value is significant at the $p=.05$ level, concluding that the performance of the two-year mathematics groups was superior to the groups with one year of mathematical instruction (this number is an estimated value found by calculations compared to The Oliver and Boyd Table II *CRITICAL VALUES OF t**).

The resulting calculation from the *t*-test comparing the one-year mathematics groups and the three year mathematics groups was -.96. This value is significant at the $p=.05$ level, concluding that the performance of the three year mathematics groups was superior to the groups with one year of mathematical instruction (this number is an estimated value found by calculations compared to The Oliver and Boyd Table II *CRITICAL VALUES OF t**).

The results of the *t*-tests performed also demonstrate a significance between the scores of the two-year mathematics

groups and the three-year mathematics groups such that the performance of the two-year mathematics groups was superior to the performance of the three-year mathematics groups (this number is an estimated value found by calculations compared to The Oliver and Boyd Table II *CRITICAL VALUES OF t^**).

SUMMARY

The findings of the research study, obtained by the comparison of t -test scores from the four groups, have been presented in this chapter. In Chapter V of this study the research will be summarized, a conclusion of the data gathered will be presented and a recommendation of how the research can be valuable will be discussed.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The problem of this study was to compare the problem solving abilities of students in grades nine through twelve that have completed either one, two, or three, thirty-six week courses in the subject area of mathematics in order to determine how much mathematical instruction is necessary as a prerequisite to the successful completion of instructional activities integral to the contemporary high school technology education curricula. This chapter will summarize the proceeding chapters, offer conclusions based on the findings of the research and present recommendations as to how the study can be useful to future studies.

Summary

The research study has presented a problem that is critical to school systems undergoing curricular changes concerning the integration of academic and practical courses. In order to provide today's youth with viable solutions to problems effecting their ability to leave school prepared for life, the integration of academic and practical courses will be necessary. More specifically, mathematics will need to be taught in an applied-technological format in order to determine whether or not mathematical instruction is crucial in order to support technological exploration of pre-engineering instructional activities within the technology laboratory. The focus of this study was to determine if high school students that have successfully completed two or three thirty-six week high school courses in mathematics are more capable of solving problems encountered during instructional activities in high school technology classes than are high school students that have completed only one thirty-six week high school course in the area of mathematics.

The research was conducted in order to compare the design and engineering problem solving abilities of Churchland High School students who have already completed either one, two, or three thirty-six week courses in mathematics. Five homogeneous

teams were made up of students who have completed one high school course in mathematics. Five homogeneous teams were made up of students who have completed two high school courses in mathematics. Five homogeneous teams were made up of students who have completed three high school courses in mathematics. Five heterogeneous groups were each made up of three students, the first having completed one high school course in mathematics, the second having completed two high school courses in mathematics, and the third having completed three high school courses in mathematics. The heterogeneous groups provided for an experimental control group. The instrument used in gathering research data for this study is produced by Pitsco, Incorporated, of Pittsburg, Kansas. The bridge building competition rules were developed with the input of various Technology Student Association competition results.

In Chapter IV, Findings, of this research study, the actual calculations from the data gathered were presented. These figures showed a relationship between more than one year of mathematical experience and improved problem-solving skills.

Conclusions

The hypothesis as stated in Chapter I of this study was:

H₁: High school students that have successfully completed two or three thirty-six week high school courses in mathematics are more capable of solving problems encountered during instructional activities in high school technology classes than are high school students that have completed only one thirty-six week high school course in the area of mathematics.

An additional second year of study within the mathematics disciplines gave students better problem-solving skills than first year mathematics students, however; there did not exist a profound gain in problem-solving skills of students with three years of mathematics over skills gained at the second-year level of mathematical instruction. There was a considerable gain in problem-solving skills when students were grouped heterogeneously by years of mathematical experience.

Components of the first year mathematics course called Algebra 1, is concerned with the cognitive manipulation of digits and figures. It is not taught in an applied manner and therefore fails to provide students with the ability to apply mathematical concepts to hands-on, problem-solving activities.

Students in the lower high school grades enrolled in the first

year mathematics course would in most cases be taking their first high school technology course. This is important because it takes many students several months to adjust to the unique quality of group-oriented, open-ended instruction that occurs in technology classrooms.

Components of the second year mathematics course called Geometry integrates elements of plane, solid and coordinate geometry. There is considerable emphasis placed on the application of logic in every day situations. This mode of instruction provides an effective means of teaching mathematical concepts that students can easily transfer to hands-on technology class instructional activities.

Students enrolled in the second year mathematics course will often also be enrolled in a second high school technology course. These students are already well adjusted to technology classroom instructional strategies. They are able to work well in groups and apply knowledge and skills to problem-solving situations.

While students enrolled in the third mathematics course called Advanced Algebra/Trigonometry are supposed to demonstrate the interdependence of real and complex numbers and their functions with application to other disciplines, this does

not always happen. The instruction within this class once again is the manipulation of numbers and figures through cognitive processes.

These students are generally being tracked into a college preparatory sequence and rarely have the opportunity to take technology courses in high school. When they are enrolled into a technology course, it is typically in their senior year, and used as an elective from their academic daily schedule.

The most successful group of students was the heterogeneous control group. This stands to reason because each of the three students are able to contribute their own unique perspective and skills from their highly varied educational backgrounds and age groups.

As a whole, the problem-solving abilities of students with more than one year of mathematics instruction were on a higher level than the problem-solving abilities of students with only one year of mathematics instruction, showing some support for the hypothesis, however; the level of significance, as determined by a series of *t*-tests was not as high as expected and did not adequately support the hypothesis.

Due to the overabundance of external variables affecting the abilities of contemporary high school students, it would be difficult

to determine curricular needs of students using only one small population from one school.

Recommendations

It is evident when reading this study and examining its findings that the effectiveness of mathematical and technological instruction depends upon the depth at which the instruction delves into actual application experiences concerned with using cognitive concepts and theories. The following recommendations are made:

-Mathematics and technology courses should be taught as an integrated and interdependent course in which concepts being taught in mathematics are used in real-life, application activities.

-High school students should be enrolled in mathematics and technology courses during every year of high school.

-Cooperative educational instructional strategies directed toward the formation of heterogeneous groups should be utilized by teachers of integrated application and academic courses in order to help ensure the adequate and complete instruction of

high school students.

-Team-teaching strategies should be used by teachers of practical and academic subject matter in order to provide high school students with better problem-solving instructional activities.

-Courses stressing the application of cognitive concepts should be well funded in order to provide students with tools and expendable supplies necessary for effective instructional activities.

-Effective instruction should progress from the introduction of simple known concepts to more complex-related concepts.

-Solutions to problems introduced during instructional activities should be open-ended and multi-faceted in nature.

-Students should have the opportunity to provide each other with ideas relating to the solution of problems introduced within instructional activities.

-Problems assigned to students during classroom instruction

should relate closely with real-world problems, and in turn, solutions to those problems should be relevant.

-Instruction should be delivered to a multitude of sensory modalities in order for all students to benefit from instructional and behavioral objectives.

BIBLIOGRAPHY

- Agoglia, P., Hacker, M., Van Dyke, A., Binder, D., "Engineering Prep," TIES Magazine, (January/February, 1992, Drexel University, PA) ISSN 1041-6587**
- Alexander, B., "The Quality Teacher's Tool Kit: Applying Total Quality Management Tools In Education," TIES Magazine, (September/October, 1993, Drexel University, PA) ISSN 1041-6587**
- Baker, G., Householder, D., "Making the Transition to a New Curriculum", Tech Directions, (August, 1992, Prakken Publications, MI) ISSN 1050-3749**
- Benson, J., "A Micro-Minicourse in Statistical Process Control," School Shop/Tech Directions, (April, 1992, Prakken Publications, MI) ISSN 1050-3749**
- Bingaman, J., Kennedy, E., Cochran, T., "A Blueprint to Revolutionize America's Schools," TIES Magazine, (November/December, 1993, Drexel University, PA) ISSN 1041-6587**
- Bottril, P., "Design as a Model for Integration," TIES Magazine, (September/October, 1992, Drexel University, PA) ISSN 1041-6587**
- Brock, Senator, W., "The SCANS Approach to Linking High School and Work," TIES Magazine, (January/February, 1992, Drexel University, PA) ISSN 1041-6587**
- Cahill, J., "Integrating Curriculum for Tech Prep," Tech Directions, (November, 1993, Prakken Publications, Inc., MI) ISSN 1062-9351**
- Cooper-Hewitt Museum Staff, "A Bridge to Learning," TIES Magazine, (November/December, 1991, Drexel University, PA) ISSN 1041-6587**

Derr, K. T., "The Real National Crisis: A Drought of Technical Students," TIES Magazine, (March/April, 1993, Drexel University, PA) ISSN 1041-6587

Eiser, L., "Math for a Reason," Technology and Learning, (March, 1993, Peter Li, Inc., OH) ISSN 1053-6728

Gauger, R., "Chem Tech and Physics Tech: The Integration of Science and Technology," TIES Magazine, (March/April, 1993, Drexel University, PA) ISSN 1041-6587

Granger, F., "Math and Magic," Tech Directions, (November, 1993, Prakken Publications, Inc., MI) ISSN 1062-9351

Hacker, M., Van Dyke, A., Binder, D., "Engineering Prep," TIES Magazine, (January/February, 1992, Drexel University, PA) ISSN 1041-6587

Howarth, C., "Searching for Solutions- a Museum Directors View of the Crisis in Education," TIES Magazine, (January/February, 1993, Drexel University, PA) ISSN 1041-6587

Hull, D., "Tech Prep: Practical Education for America's Work Force," Tech Directions, (March, 1992, Prakken Publications, PA) ISSN 1050-3749

Husher, H., "Closing the Gap: Women in Technology," Tech Directions, (February, 1993, Prakken Publications, MI) ISSN 1050-3749

Karsnitz, J., "So Why Are We Building Bridges?," TIES Magazine, (March/April, 1993, Drexel University, PA) ISSN 1041-6587

Kinnaman, D., "Technology Makes Choice Inevitable," Technology and Learning, (January, 1994, Peter Li, Inc., OH) ISSN 1053-6728

Kriegh, M., "Pillars of the Community: Architectural Challenges for Middle and High School Students," TIES Magazine, (January/February, 1992, Drexel University, PA) ISSN 1041-6587

Liao, T., "Liberal Education in Mathematics, Science, and Technology: A Way Forward," TIES Magazine, (March/April, 1993, Drexel University, PA) ISSN 1041-6587

- Lynch, C., Olmstead, E., Math/Matters Book 2. An Integrated Approach**
(1993, South-Western Publishing Company, OH)
ISBN: 0-538-61120-0
- Markland, J., "*Drawing on Visual Skills*," TIES Magazine,** (September,
October 1991, Drexel University, PA) ISSN 1041-6587
- McGhan, B., "*How I Learned to Quit Being a Snob and Love Vocational Education*," Tech Directions,** (April 1992, Prakken
Publications, Inc., MI) ISSN 1062-9351
- McClelland, A., "*Lessons from the Constitution and the Stage*,"**
TIES Magazine, (March/April, 1993, Drexel University, PA)
ISSN 1041-6587
- National Research Council, "*Everybody Counts: A Report to the Nation on the Future of Mathematics Education*"**
(1989, National Academy Press, Washington, D.C.)
- Ranken, T., "*Vo-Ed-Applied Learning for All*," Tech Directions,**
(November, 1993, Prakken Publications, Inc., MI) ISSN 1062-9351
- Reich, R., "*Home-Grown Transitions: School-to-Work*," TIES Magazine,** (January/February, 1992, Drexel University, PA)
ISSN 1041-6587
- Ryan, J., "*The Critical Role of Occupational Education*," Tech Directions,** (October, 1992, Prakken Publications, MI)
ISSN 1062-9351
- Salvadori, M., "*Why it is Difficult to Teach Math to American Students*," TIES Magazine,** (November/December, 1991, Drexel
University, PA) ISSN 1041-6587
- Stadt, R., "*More Vocational Education and Less General Education*," School Shop/Tech Directions,** (November, 1991,
Prakken Publications, MI) ISSN 1050-3749
- Stephens, R., "*Why is the Department of Energy Involved in Education? Why Not?*," TIES Magazine,** (November/December,
1992, Drexel University, PA) ISSN 1041-6587

Todd, R., Doyle, M., Hutchinson, P., "Project Update- Upgrading Practice through Design and Technology "Engineering" Education... A New Paradigm for Schooling?," TIES Magazine, (May/June, 1993, Drexel University, PA) ISSN 1041-6587

Todd, R., McCrory, R., Todd, K., Understanding and Using Technology. (1985, Davis Publications, Inc., MA.) ISBN: 0-87192-165-0